P
Med
H

Harvard University. Medical School

gical
Medical
Dental

Dept

THE DIVISION OF SURGERY

OF

THE MEDICAL SCHOOL OF HARVARD UNIVERSITY

STORAGE

REPORT OF RESEARCH WORK, 1903-1904

SEPTEMBER, 1904

Bulletin No. III

LIBRARY
MAR 7
UNIVERSITY

BOSTON
MASSACHUSETTS
U. S. A.

CONTENTS.

PAGE

A Study of Amputations of the Lower Extremity.
Fred T. Murphy 3

Experimental Decapsulation of the Kidneys.
N. H. Gifford 14

Coagulation-time of the Blood.
F. T. Murphy and A. H. Gould 24

Enterostomy in Peritonitis.
Robert B. Greenough 29

Compliments of
The Division of Surgery
of
The Medical School of Harvard University.

CONTENTS

A Study of Amputatio

Fred T.

Experimental Decaps

N. H.

Coagulation-time of

F. T. M

Enterostomy in Peritonitis.

Robert B. Greenough 29

THE DIVISION OF SURGERY

OF

The Medical School of Harvard University

REPORT OF RESEARCH WORK, 1903-1904

SEPTEMBER, 1904

A STUDY OF AMPUTATIONS OF THE LOWER EXTREMITY.

BY FRED T. MURPHY, M.D., BOSTON.

For the Division of Surgery of the Medical School of Harvard University.

AMPUTATIONS of the lower extremity, as a class, offer little of technical interest to the operator. They are usually traumatic cases of such extent that the saving of the patient's life is the main question. The operator is apt to consider the immediate result, while to the patient the ultimate usefulness of the stump is of major importance. Generally speaking, a good immediate result means a good end result, but in amputation this may be far from the truth.

When artificial appliances were in the crude state, the principle was taught, " save as much as you can," and to a remarkable degree such is the opinion held at the present day. Observations of numerous failures to obtain a serviceable stump by following this teaching suggested to me the investigation of the relative values of the various methods of amputation of the lower extremity as regards the production of a useful stump.

Through the courtesy of the staff of the Massachusetts General Hospital the hospital records were placed at my disposal, and Dr. J. Collins Warren kindly allowed the use of his name in correspondence with the patients and with the manufacturers of artificial limbs, for both of which favors I am deeply indebted.

Data were obtained from three sources, namely: the hospital records, the patients and the makers of artificial limbs.

In order to get an idea of the type of cases and the immediate results, that is, the results before leaving the hospital, the records of five hundred cases were abstracted. These cases were taken as nearly as possible in consecutive order and include the years from 1889 to 1901 and part of 1888 and 1902, but owing to the irregularity of the diagnoses it was not possible to depend upon the card catalogue, and certain few cases may have been overlooked in going through the individual record books.

The following list of questions was sent to each of these patients who had left the hospital alive, with a note asking them to answer the questions and return them to me in case they were not able to come to the hospital for examination:

" Do you wear an artificial limb? If not, why? How long after the operation was it before the tenderness would allow one to be worn? Can you walk without crutch or cane? Can you do any manual labor? What? Do you ever have pain in the stump? Is the pain localized in the end of the stump? Does the leg draw up with cramps? Has there been any sensation as if the toes were cramped? If so, how long before this sensation wore away? Has the weather any effect on the stump? Does the stump ever swell or discharge? Does the artificial limb cause pain or discomfort? Have you had any operation since the first amputation? Who made the artificial limb? What did it cost? How often has it been necessary to have the limb repaired? About what has been the cost of such repairs? After your experience, what suggestions would you make regarding the treatment of an amputation such as you have had? "

Recognizing the wide experience and ability of the best makers of artificial limbs, another list of questions was sent to eleven of the well-known firms of the East and West. These gentlemen have been more than courteous in their efforts to help me, both by replying by letter and pamphlet and by calling in person. I take this occasion to thank them, and to urge a closer coöperation between the surgeon and the prosthetician, for it is by this means that the problem will be worked out and the best results given to the patients.

The following table shows the class of cases and the mortality in the hospital:

TABLE OF AMPUTATIONS.

	Total.	Died.
For crush:		
(Single)		
Thigh	66	27
Leg	172	8
Partial foot	32	1
(Double)		
Thigh	1	
Thigh and tibia	11	2
Thigh and partial	1	
Tibia	19	6
Tibia and partial	5	1
Partial	1	
For bad stumps of		
Thigh	11	
Leg	35	1
Partial	6	
For sepsis:		
Thigh	11	4
Leg	4	1
For gangrene:		
Thigh	31	11
Thigh and leg	1	1
Leg	23	12
Partial (double)	1	
For new growth:		
Double thigh	1	1
Thigh	32	5
Leg	12	2
For tuberculosis and osteomyelitis:		
Thigh	17	1
Leg	6	
Partial	1	
	500	84

The general and local conditions in individual cases exerted such an influence upon the result and upon the technic of the

operation that statistical comparisons, either as to the immediate results or the mortality, would be impossible and unfair. But certain facts were boldly emphasized. As might be expected, the amputations for new growth did much better, as far as the healing of the stump was concerned, than those done for trauma and gangrene. In general, the immediate results of all the amputations as compared with the perfect healing seen in other classes of clean cases, were most disappointing. Union by first intention was the marked exception rather than the rule. Ordinarily in clean cases three weeks may be taken as a surgical unit of time which represents by a slight addition or subtraction the time of convalescence, but in these amputations it would be hard to fix a limit of time, so persistent were the indolent granulations and sinuses. In many instances the use of bruised tissue for emergency flaps was necessary, and in these cases the failure to obtain satisfactory healing was to be expected, but not infrequently the poor result seemed to be due to the technic rather than to the unavoidable conditions. These failures, with few exceptions, were due to the infection of the clot of blood and serum which had collected beneath the flaps or were caused by the failure to provide a suitable covering for the end of the bone. The skin flap with a circular incision was the one most often used, and it seems to me the least desirable, except in such regions as the lower third of the leg and when demanded by necessity. Certainly, the muscle flaps in the thigh and the upper part of the leg gave much more favorable results than when the skin alone was used.

Unless the soft parts were carefully approximated and held by buried sutures, the drained cases did noticeably better than when the attempt was made to obtain a complete first intention. These attempts not infrequently led to the following sequence: first intention of the skin, about the fourth to sixth day, expression of the blood clot by opening the line of incision, infection causing a sinus or further opening of the incision to pack the cavity, retraction of the flap sometimes resulting in protrusion of the bone followed by reamputation or skin-graft. Where muscle flaps were obtainable, the method of suturing the periosteum over the end of the bone and approximating the muscles and fasciæ by buried or mat-

trass sutures gave excellent results. There were no instances of osteoplastic flaps except in amputations at the ankle-joint. As a routine, the cases were operated as soon as it was possible to obtain a surgeon, so that no statement can be made as to the relative value of immediate or delayed operation in the traumatic cases. Judging from the records, the shock of amputation *per se* below the upper third of the thigh was not marked.

Except for the question of flaps and drainage, the immediate results of the routine leg and thigh cases have no special interest in connection with this paper. A class of amputations, such as the so-called Syme's, Pirogoff's, Chopart's, Lisfranc's, Hey's, etc., with their modifications, does, however, illustrate certain points which it will be well to bear in mind in considering the ultimate utility of these operations.

There were 44 operations of this class in which the immediate results could be judged. They included 12 tarso-metatarsal amputations, 3 of which were followed by reamputation; 17 medio-tarsal amputations with 4 reamputations, and with 1 case which had not healed at the end of nine months and another which went on crutches for eleven months; 7 disarticulations at the ankle-joint, of which 1 was advised to have a reamputation, and another in which sinuses persisted; 8 Pirogoff's with 1 reamputation and 3 cases with faulty position of the fragment of the os calcis. In addition to these more marked failures, these amputations of the foot were generally slow to heal.

Failure to obtain a good result in about $33\frac{1}{3}\%$ is significant.

The opinions of the makers of artificial limbs were in the main remarkably unanimous. Regarding minor details there were differences, and rarely the position was taken that any stump could be satisfactorily fitted.

In the following comments I have endeavored to express the prevailing idea and that which seems to me to be the most reasonable.

Here, as was the case in considering the immediate results, exceptions may be cited to disprove any statement, but in general, that is, to obtain the greatest benefit to the greatest number, the experience of the makers of artificial limbs supports the following conclusions:

The Lisfranc's, Hey's, and Chopart's and the irregular midtarsal amputations were considered in a single class. The preservation of the attachment of the *tibialis anticus* gives a theoretical advantage to Lisfranc, but practically it is open to the same objections as the others, namely: a weak supporting arch and a tendency to extension of the stump even though the Achilles tendon be divided. Given an ample flap which assures the placing of the scar on the dorsum of the foot so that it will not be irritated by pressure, and a perfect result without extension of the stump, it was held by the makers that these operations were acceptable, but so rarely was this perfect result seen that generally such amputations were condemned. Even under the most favorable conditions, it was questioned whether these amputations gave as strong a supporting leg as a tibial stump. Any appliance, other than a simple cosmetic false foot which offers little or no support, is cumbersome and difficult to fit with comfort to the patient.

Operations of the type of the Syme and the Pirogoff formed the next group to be considered, and they, too, were disapproved. The Syme, or the modification with the lateral flap when perfect, offers simply a peg leg. Displacement of the heel pad so as to bring the cicatrix into bad position had been the general experience. The bone flap of the Pirogoff increases the length of the leg, and with a perfect result makes a smoother stump. Malposition, however, of the bony fragment or of the cicatrix had been the rule. The greatest difficulty had been found in providing a satisfactory apparatus after these operations.

Going above the ankle-joint the opinion was ananimous that the long stumps obtained in amputations through the lower third of the leg were undesirable. Different levels were suggested, varying between the middle of the middle third to the junction of the middle and lower thirds. In inches, lengths between 6 and 10 inches measured from the lower border of the patella were acceptable. The longer stumps have been found to show a tendency to swell at the end, and the greater leverage without material gain in handling the foot increased the liability of play in the socket, thus causing irritation of the anterior border of the tibia. A stump shorter than six inches has been found to decrease the usefulness of the leg by

FIG. 1. Disarticulation at ankle-joint. Shows the displacement of the heel-pad "A" and the tender point "B" on the anterior edge of the tibia.

FIG. 2. Tibial stumps, 10 inches and 4½ inches in length. The shorter stump is the more useful.

NOTE.—The writer is indebted to Mr. Walter J. Dodd of the Massachusetts General Hospital for the illustrations used in this paper

FIG. 3. Pirogoff and 4-inch tibial stump. The short tibial stump is the more useful.

FIG. 4. To show how short a tibial stump can be and yet afford perfect function.

FIG. 5. Six-inch tibial stump. Good free end pad. No discomfort. Perfect function. Patient weighs 206 pounds.

FIG. 6. Bad conical stump of thigh.

FIG. 7. X-ray of stump of a tibial amputation, showing bony change caused by constant irritation of the anterior edge of the tibia; also illustrates the common error of leaving the fibula too long.

FIG. 8. Cumbersome apparatus seen on Syme's amputation. Compare with Fig. 9.

FIG. 9. Ordinary artificial leg for tibial amputation For comparison with Fig. 8.

lessening the power of leverage. A tibial stump two inches long was accepted as the minimum which would give a satisfactory bearing for an artificial leg which would preserve the function of the natural knee joint. Amputations necessitating a shorter tibial stump opened the question of sacrificing the knee. The old operation of saving the short tibial stump gives with flexion a good, serviceable, end-bearing but cumbersome leg. As in amputations through the joint, it necessitates a bulky apparatus and in the sitting posture makes one thigh longer than the other. Amputations through the joint were generally considered to possess no advantage over those above the condyles, and to have beside the disadvantage of necessitating a clumsy apparatus and to be liable to irritation over the bony prominences.

Gritti's procedure of placing the patella at the end of the femur was not advised. When successful the end bearing is good, but the bone is apt to be displaced, and even the perfect result is open to the same objections as the other knee joint operations.

Above the knee it was advised that the stump be left as long as possible, provided the condyles of the femur be removed. Measured from the perineal fold, any thigh stump longer than five inches was considered to be satisfactory and useful. Stress was laid on the importance of obtaining a good, not redundant, end pad; the necessity of beveling the bony prominences, such as the anterior border of the tibia, and careful resection after traction of the nerves was emphasized.

In the short leg amputations it was suggested by some that the fibula should be sub-periosteally resected, and in all cases that it be cut off at a higher level than the tibia. " End bearing " was considered as desirable but not at all as an essential.

One hundred and sixteen of these patients were seen and personally examined or followed by letter. Results are considered as " fine " when the patient is able to walk without a cane and to do ordinary manual labor, as " good " when able to walk with a cane or with slight discomfort and to do light work.

In this series there were 35 cases of amputation of the thigh. Seven died without using artificial limbs to any extent,

four from sarcoma, two from tuberculosis and one from gangrene. Five have not tried to use artificial limbs, either because the leg could not be obtained or because they are too comfortable on crutches. Nine are "fine" results and are able to do practically the same work as before the injury. Nine cases are classified as " good " results. Three are bad, two being in old men so weak that the uninjured leg will not bear the weight of the body, and one a conical stump in a child who was operated at four years of age. One patient has new bone reforming in the stump after an excision at the hip joint and will ultimately be able to wear an artificial leg. Another has a fine stump without evidence of neuromata or irritation, but thus far has not been able, on account of pain, to use an artificial leg. From these cases no special conclusions could be drawn. Where muscle flaps had been taken, the covering at the end of the stump seemed much more fitted to stand rough usage than when the skin alone had been used.

Sixty-one cases of leg amputation were followed. Six have died, one of whom, at the time of death, would be classed as a " good " result. Six as yet have no artificial legs, four of whom are waiting to be fitted, one had sloughing of the flaps and the bone still irritates the skin, and one is an old man with a tender adherent flap. Forty are "fine" results and nine are classified as "good."

These tibial amputations illustrated most graphically the suggestions made by the prostheticians. The most perfect results were seen in the shorter tibial stumps, that is, about six inches. The long stumps from amputations of the lower third, almost without exception, caused trouble by swelling and from the irritation on the anterior edge of the tibia. Several cases were seen where the too long fibula caused marked tenderness in the end of the stump. The extra leverage above six inches gave no advantage. The shortest tibial stump observed was two and one-half inches with which the patient was able to do active and hard manual labor. On the whole the slight amount of disability caused by the loss of a foot was remarkable. The claim sometimes advanced by manufacturers that shoulder straps for support of the leg are not necessary was not borne out by these cases, as their use was almost universal.

The ten cases of double amputation are tabulated in order that a comparison between the stumps may be more readily seen :

Pirogoff — painful.
Partial — fine.

Pirogoff — fine; patient would much prefer a tibial stump.
Tibia, 4 inch,much the stronger leg.

Chopart — good, but patient wishes it were a tibial amputation.
Middle third of tibia, fine, much the stronger leg.

Tibia, 10 inch, fine.
Tibia, 2.5 inch, fine.

Tibia, 7 inch, fine.
Tibia, 8 inch, fine.

Tibia, 7 inch, fine, considerably the stronger leg.
Tibia, 9 inch, fine.

Tibia, 4.5 inch, fine, much the stronger leg.
Tibia, 10 inch, fine.

Thigh above condyles, fine.
Mid-tibia, fine.

Partial foot, fine.
Middle and lower third tibia, fine.

Mid-thigh, good.
Mid-tibia, good.

With the exception of the last case, who has been fitted with the artificial legs only a short time, these patients with a double amputation have experienced remarkably little discomfort. There are included laborers who do hard work and youngsters who go to school and play ball.

The partial amputations of the foot and those at the ankle-joint are also given in tabulated form:

Syme's, fine.
Syme's fine.
Syme's, good, but patient would much prefer a short tibial stump.
Syme's, good, but there is bad displacement of heel pad and scar, and patient wants a reamputation.
Syme's (lateral flap), good, but patient would prefer a tibial stump.
Lisfranc's, good, but considerable pain.
Chopart's, fine; walks well but not so strong as a good tibial amputation.

Chopart's, fine.
Chopart's, good, but with apparatus makes a clumsy foot.
Chopart's, fine, but not satisfactory with artificial limb.

A failure of 33⅓% in the immediate results and the unsatisfactory end results must, it seems to me, condemn all of the partial amputations of the foot or at the ankle-joint.

The summary of the replies to the questions which have not been considered in the preceding paragraphs is as follows:

Simple tenderness in the stump prevented the wearing of an artificial limb for from two months to two years. In the majority of cases the stump was ready for the leg in from five to seven months. Intervals of slight pain in the stump was the rule. The pain was rarely localized in the end of the stump, but was referred to the foot. The leg itself was universally reported as being free from cramps, but the absent toes almost as generally were subject to periods of more or less severe discomfort. To a very slight degree the sensation in the toes persisted, usually growing markedly less after about the first year. Opinions regarding the influence of the weather were most variable. In some, extreme cold caused discomfort, while in others heat was to be dreaded, and still another group felt a storm or an east wind. This discomfort, which was experienced by about one third of the patients, was apparently no more severe than is found in the average individual with a " rheumatic tendency." Only in the long tibial stumps or with improperly fitted sockets was there marked swelling or discharge from the stump. Any artificial appliance must of necessity cause some discomfort, but generally speaking the limbs were worn with remarkable ease. Twenty-four cases had undergone some secondary operation after leaving the hospital. Incompleteness in the replies prevents a definite statement regarding the exact character of these operations, but usually they had been of a trivial nature, such as the opening of an abscess or the removal of necrotic bone or neuromata. As " suggestions," nearly all of the patients confined their remarks to the after-treatment of the stump. They complained, as did the makers of artificial limbs, that usually no directions were given on leaving the hospital as regards bandaging the stump. If left alone, the soft tissues hypertrophy and become flabby, necessitating later the wearing of a " shriner " before a socket can be fitted. In order to prevent

this the stump should be bathed frequently, either with cold water or some mild astringent solution, and kept bandaged with flannel under moderate tension so that there will be slight compression, or should be encased in a proper leather support. The cost of the limbs was from $50 to $100. With ordinary use and with a good make of leg, repairs were necessary once or twice a year. Their cost was, as a rule, insignificant. Often the repairs were made by the wearers themselves.

It is not the purpose of this paper to attempt to consider the merits or faults of the various styles and makes of artificial legs, but if it were, I should have great difficulty in condemning wholly any one type. Given a first-class artificial limb, whatever the make may be, and an intelligent patient with a satisfactory stump, and the functional result will be remarkably good. Failure on the part of the patient to practise a proper gait and to endeavor to correct the faults is, it seems to me, more often to blame than is the artificial leg.

The conclusions warranted by these observations are as follows:

Anterior and posterior muscle flaps when obtainable are to be preferred to the circular cuff of skin.

The fibula should be cut off at a higher level than the tibia in leg amputations, and care should be taken to bevel off bony prominences such as the sharp anterior tibial edge.

Suture of the periosteum and approximation of the muscles and faciæ is desirable.

Drainage of the stump is advised, unless the dead space is obliterated by means of buried sutures.

Partial amputations of the foot or amputations at the ankle-joint, except under unusual conditions, are not as satisfactory as those above the ankle-joint.

Tibial stumps between 6 and 8 inches long are the most serviceable.

Amputations through the knee-joint are inferior to those just above the condyles.

The longer the thigh stump the better, provided the condyles have been removed.

In general, in tibial amputations down to 4 inches and in thigh amputations down to 5 inches, sacrifice bone in order to obtain good muscle flaps.

EXPERIMENTAL DECAPSULATION OF THE KIDNEYS.

BY N. H. GIFFORD, M.D., BOSTON.

From the Laboratory of Surgical Pathology. For the Division of Surgery of the Medical School of Harvard University.

THIS article contains the results of a year's work on the experimental decapsulation of kidneys, performed on animals in the surgical laboratory of the Harvard Medical School, aided by the suggestions of Dr. E. H. Nichols.

DR. H. A. Johnson, in the *Annals of Surgery* for April, 1903, and Albarran and Bernard, in the Société de Biologie in June, 1902, have published papers bearing on the first part of my work, that of the rabbit series. As my results differ in many respects and there are some additional observations, I take the liberty of presenting this paper.

The experiments have been conducted upon rabbits and dogs.

In each rabbit or dog I have decapsulated one kidney, always the left because it is normally smaller than the right by one fourth to one third and lies more inferiorly, thus giving greater ease of access from lumbar incision. The animals were etherized, the hair clipped, the remaining hair removed by sulphur paste, and the operation performed, as far as possible, under aseptic precautions. In no case, either in rabbits or dogs, have I found the peritoneum so closely adherent over the capsule of the kidney as to be torn in the delivery of the kidney into the wound for decapsulation. After delivery of the kidney the capsule was split along the greater curvature from pole to pole, stripped off by the help of forceps, if necessary, and the kidney returned to its original position in the retro-peritoneal fat. The wound was then closed with deep, interrupted, heavy silk sutures, and the animal returned to the pen to be killed after an allotted time had elapsed. The animals were killed by the injection into the lung of from one-eighth to one-fourth grain strychnine sulphate.

The specimen was preserved immediately after removal in Zenker's fluid, by placing the kidney in the fluid, intact, for one hour, and then cross-sectioning into slices, two to four mm. thick. This method prevents slipping or tearing away of the

capsule by the knife, as is true in making fresh sections. In all cases the unoperated kidneys were removed at autopsy and preserved in the same manner to be examined as controls.

The rabbit series comprises two, four, six, eight, ten, and thirty-one days and six months after operations.

Two days: The left kidney, by measurement, is one-third larger than the right. There is a thin layer of blood clot about the kidney.

Microscopically. — In places about and external to the cortex few very young connective tissue cells appear. There are no connective tissue fibrils by Mallory's connective tissue stain. There is moderate congestion of all the vessels and capillaries in the kidney substance. No change in renal epithelium appears.

Microscopically — The right kidney shows a capsule two to four cells thick.

Four days: The left kidney is one-fourth larger than the right. Thin, fibrinous adhesions with little blood clot appear about kidneys.

Microscopically. — A layer of new connective tissue cells appears on the cortex, five to seven cells thick, showing by Mallory's connective tissue stain a few connective tissue fibrils. There are new blood vessels from the cortex and a slight infiltration with polynuclear leucocytes, plasma cells and eosinophiles. The capillaries of the outer cortical zone show slight injection. There is no change in the renal epithelium.

Microscopically. — The right kidney shows a capsule two to four cells thick.

Six days: The left kidney is one-fourth larger than the right. The blood clot has disappeared. The kidney is rather firmly imbedded.

Microscopically. — There is no injection of the vessels of the kidney substance. A new capsule appears about the kidney, ten to twenty cells thick, rather rich in blood vessels, showing by Mallory's connective tissue stain numerous medium long, well-formed intercellular fibrils. The cells of the outer layer of the new capsule are rich in yellow pigment. There is no change in renal epithelium.

Microscopically. — The right kidney shows a capsule three to five cells thick.

Eight days: The left kidney is one-fifth to one-fourth larger than the right. There is no blood clot.

Microscopically. — No injection of the vessels appears. There is a new capsule of connective tissue ten to fifteen cells thick, rather rich in connective tissue fibrils and blood vessels. There is no change in the renal epithelium.

Microscopically. — The right kidney shows a capsule two to five cells thick.

Ten days: The left kidney is one-fourth larger than the right and is firmly anchored. There is no blood clot.

Microscopically. — A new capsule, rather rich in connective tissue fibrils and blood vessels, appears, ten to fifteen cells thick. There is no injection. There is no change in the renal epithelium.

Microscopically. — The right kidney shows a capsule two to four cells thick.

Thirty-one days: The left kidney is slightly larger than the right, and is firmly anchored.

Microscopically. — The vessels are not injected. A new capsule appears, seven to fifteen cells deep, with long connective tissue fibrils in abundance, and a few new blood vessels. There is no change in the renal epithelium.

Microscopically. — The right kidney shows a capsule two to four cells thick.

Six months: The left kidney is approximately the same size as the right. The capsule of the left kidney shows a few spots two to three mm. in diameter, yellowish and opaque, but not appreciably thick to touch. The remainder of the capsule is transparent like that of the right kidney.

Microscopically. — There is a capsule of connective tissue two to four cells deep, with a few long, connective tissue fibrils closely packed and rather sparsely supplied with blood vessels. Sections through the opaque areas show a capsule four to eight cells deep. Except these slightly thickened areas, whole section of left kidney not different from that of right, whose capsule is from two to four cells deep. No change in renal epithelium.

From the above we see that as early as the second day after the operation new connective tissue cells begin to appear in the clot about the decapsulated kidney. On the fourth day

connective tissue fibrils begin to be formed, and by the tenth day a new capsule, rich in blood vessels and three to four times normal thickness, surrounds the kidney. That the capsule has been entirely removed by the operation shows in the two-day specimen and also in the three controls which I made, after seeing the article by Johnson in which he claims the impossibility of entirely removing the inner capsule. In the kidney substance there is a rather well marked intertubular congestion up to the fourth or fifth day, but no change in the cells of the blood vessel walls is observed at any time. The tubules and glomeruli remain unchanged.

In the operation when the capsule is split, it immediately draws back and the kidney pops out as if under tension. This is probably due to the congestion caused by putting the renal vessels on stretch and thus narrowing their caliber. This would have more effect on the veins because of their relatively thinner walls. This increase in size, however, persists.

The operated kidneys, as can be seen by the above, are increased in size up to thirty-one days afterwards. At the end of six months, however, they return again to nearly normal size, and at the same time the capsule is but little thicker than normal.

In the dog series sections were made three, eight, and fifteen days after operation on normal animals.

THREE DAYS: The left kidney is one-fourth larger than the right. There is considerable blood clot in the perirenal tissues but the kidney is held fairly well in place.

Microscopically. — There is moderate injection of the subcapsular vessels. There appears a capsule composed of young connective tissue cells, fifteen to twenty-five cells deep, with few rather short connective tissue fibrils and rather rich in new blood vessels. Both the left and right kidneys show areas in cortex of slight increase of connective tissue, including atrophied glomeruli and a few infiltrating lymphoid and plasma cells. There is no change of the renal epithelium.

Microscopically. — The right kidney shows a capsule six to twelve cells thick.

EIGHT DAYS: The left kidney is one-fourth larger than the right. Very little blood clot appears in the neighborhood. The kidney is firmly anchored.

Microscopically. — No injection of vessels appears. The capsule is composed of new connective tissue, ten to twenty cells thick, with medium long, wavy, connective tissue fibrils, and rather rich in newly formed blood vessels. There is no change in the renal epithelium.

Microscopically. — The right kidney shows a capsule six to twelve cells thick.

Fifteen days: The left kidney is one-sixth larger than the right.

Microscopically. — There is no injection of the vessels. A new capsule is present, composed of connective tissue with a few blood vessels, fifteen to twenty-five cells thick, and with quite numerous connective tissue fibrils. The new connective tissue of the capsule connects in places with some new connective tissue, running a short distance into cortex between the tubules. There is no change in the renal epithelium.

Microscopically. — The right kidney shows a capsule seven to fifteen cells thick.

Acting upon the idea that while no definite histological changes might follow the decapsulation of kidneys of normal animals, decapsulation of kidneys showing existing pathological changes might give more fortunate results, in that the conditions present were like those in the clinical cases which have been so successful — I next tried to induce nephritis. I chose nephrolytic serum as the best means of inducing nephritis. The nephrolytic serum was obtained by injecting an emulsion of washed dog's kidney subcutaneously into rabbits at three-day intervals, and at the end of two weeks the rabbits were bled and the serum injected into apparently healthy dogs.

Eight hours: A dog was injected with 0.5 cc. nephrolytic serum. No symptoms resulted. Six days later 2.0 cc. of nephrolytic serum were injected with no symptoms immediately following. On the fifth day after the second injection the dog was reported in convulsions and coma (with diarrhea and vomiting and anuria). Ether was administered and the left kidney decapsulated through the lumbar incision. A wedge-shaped piece of the cortex was removed for examination. After coming out of ether the convulsions and coma persisted, the convulsions becoming more frequent and the dog weaker, until he died eight hours after the conclusion of the operation. Autopsy

revealed no gross lesions other than congestion of all the organs.

Microscopically. — The piece removed from the left kidney at the operation shows swelling of the tubular epithelium, with obliteration of the lumen and separation from the basement membrane.

Microscopically. — The decapsulated left kidney shows the capsule is removed completely from two thirds of the surface, being replaced by blood clot. There is marked injection of the intertubular vessels and the larger vessels of the pyramids. The epithelium of the parenchyma is swollen, with solid staining or absent nuclei, and everywhere is torn from the basement membrane. There is no increase of the intertubular connective tissue.

Microscopically. — The right kidney shows a capsule six to ten cells thick. There is less injection than in the left, but the remaining lesions are essentially the same. (Acute Desquamative Nephritis.)

Microscopically. — The rest of the organs show nothing abnormal, except marked injection of the vessels and small areas of hemorrhage into the spleen and the lungs.

Two days: April 29, 1903. Dog injected with 0.5 cc. nephrolytic serum.

May 11, 1903. No symptoms. 0.5 cc. nephrolytic serum injected.

June 11, 1903. No symptoms. 1.0 cc. nephrolytic serum injected.

June 19, 1903. No symptoms. 0.5 cc. nephrolytic serum injected.

July 21, 1903. No symptoms. 1.0 cc. nephrolytic serum injected.

Sept. 24, 1903. The dog was reported sick, frothing at the mouth and in convulsions. One-half grain morphine sulphate was administered followed by ether and operation. The left kidney was decapsulated and the right kidney removed through the lumbar incision. The dog appeared perfectly well following the operation, with no more convulsions. At the end of forty-eight hours the dog was killed with three-eighths grain strychnine sulphate. The left kidney was one and one-half times as large as right, which had been removed at the time of the operation.

Microscopically. — The left kidney shows that the capsule has been entirely removed over half the convexity and is replaced by blood clot containing at all edges a few new connective tissue cells. At the edge of the denuded cortex are a few short, thick, wavy, connective tissue fibrils. In the cortex are areas of intertubular infiltration of transitional plasma cells, varying in size from that of a glomerulus to five or six times as large. These infiltrating cells are in active mitosis, and the glomeruli and tubules included are degenerating. There are a few areas of slight increase of connective tissue in the cortex, including atrophied glomeruli. The tubules appear rather widely separated, and the tubules themselves are dilated and contain circular recticulum.

Microscopically. — The right kidney shows a capsule three to five cells thick, rich in long, thin, closely packed, connective tissue fibrils. The description of the cortex is the same as in the operated left kidney above.

Diagnosis. — Acute non-suppurative interstitial nephritis.

Eight days: A dog was injected with 0.5 cc. nephrolytic serum. One month later the left kidney was decapsulated through the lumbar incision, and a wedge-shaped piece of the cortex removed for examination at the time of the operation. The dog was killed eight days after the operation.

Microscopically. — The piece of the left kidney removed at the time of operation shows capsule absent.

Microscopically. — The left kidney shows a capsule fifteen to thirty cells thick, composed of new connective tissue cells with long, thin fibrils between, and without are some areas of blood clot undergoing organization. The cortex shows no injection of the blood vessels. In the cortex are areas of lymphoid and plasma cell infiltration, slightly larger than the glomeruli, rather more numerous towards the medulla, and with slight increase of connective tissue in and about these areas. The glomeruli included show slight to marked atrophy with fibrous changes. There is no general increase in the intertubular connective tissue. The epithelium of the tubules is normal.

Microscopically. — The right kidney shows a capsule ten to fifteen cells thick. The cortex and medulla show the same condition as in the left.

I then produced kidney infarction in dogs in two cases, in

one of which I decapsulated the kidney and in the other, I did not.

Four days (unoperated): Through the abdominal incision the left renal artery and left ureter were tied off. The animal was killed four days later.

Microscopically. — The left kidney shows capsular and pericapsular connective tissue, much thickened, containing fibrin, red blood globules, polymorphonuclear leucocytes and new connective tissue cells. The capsule is thirty to forty cells thick, with fairly short, thick, wavy, connective tissue fibrils, both in towards and into cortex and outside of original capsule. There is a moderate increase of the intertubular connective tissue in the outer zone of the cortex. The cortex itself shows the epithelium to be necrotic, with polymorphonuclear leucocytes within and without cells. In medulla are a few areas of apparently normal epithelium. The vessels are everywhere injected.

Microscopically. — The right kidney shows a capsule seven to twelve cells thick. The section of the kidney substance is in every respect normal.

Six days (operated): The left renal artery was tied off through the left abdominal incision and the kidney decapsulated. The animal was killed six days later. The left kidney was slightly smaller than the right.

Microscopically. — The left kidney shows a capsule twenty to thirty cells thick, composed of new connective tissue cells with medium, long, wavy, connective tissue fibrils in between them, and containing in their meshes numerous red blood globules. All the kidney substance, except one fourth about the hilus, is infarcted. Beneath the new capsule a few young connective tissue cells extend in about the intertubular vessels.

Microscopically. — The right kidney shows a capsule seven to ten cells thick. There is no increase of the intertubular connective tissue. The epithelium and glomeruli are normal.

Finally, I removed the left kidney from a dog, and five and one-half weeks later decapsulated the right through the lumbar incision. At the end of eight days the dog was killed. The right kidney at time of operation was one and one-half times size of the left, which had been removed.

Microscopically. — The right kidney shows a capsule ten to twenty cells thick, with new connective tissue cells and medium long, fairly thick and slightly wavy connective tissue fibrils. Fairly numerous blood vessels appear in it. The intertubular blood vessels and the connective tissue are unchanged. The glomeruli and tubular epithelium appear normal.

From the dog series I find that, after decapsulation of the kidneys of normal dogs, of dogs after nephrolytic serum with the nephritis apparently induced thereby, and after the decapsulation of infarcted kidneys of dogs, and of kidneys of dogs with additional work thrown upon them by the removal of the kidney of the other side, the same results obtain as in the rabbit series. There are no new anastomosing vessels between the capsule and the cortex. Up to two or three days there may be a rather marked cortical injection. A new capsule begins to be laid down by the tenth day. There is no change in the kidney epithelium or the glomeruli following the decapsulation. The kidney is increased in size immediately following the operation.

SUMMARY.

Following the decapsulation of kidneys in rabbits, in normal dogs, in dogs with induced nephritis, in dogs with infarcted kidneys, and in dogs with normal kidneys but with additional work thrown upon them, I find the following conditions:

1. In all my cases of two days and under and in my controls the entire thickness of the capsule had been removed over two thirds of the surface by the operation of decapsulation.

2. There is a certain amount of intracapsular tension in undecapsulated kidneys, normal or with nephritis, as shown on removal of capsule.

3. There is an immediate increase in size of decapsulated kidneys persisting up to one month at least; afterwards, a decrease to approximately normal size complete at end of six months.

4. There is congestion, moderate in degree, most marked in the intertubular blood vessels in cortex, lasting three to five days after the operation.

5. No histological change in the renal epithelium follows the operation of decapsulation of kidneys.

6. A new capsule, very vascular, at first, two to four times thickness of old, is well marked at end of eight days. At end of six months it returns to approximately the normal thickness and vascularity. The new capsule arises chiefly from the connective tissue cells of the intertubular connective tissue, but in part from the retro-peritoneal connective tissue which is present in the new bed of the kidney.

7. No new vessels are formed which anastomose with those of the kidney.

8. The increase in size is due primarily to the increase in blood supply, possibly resulting from the removal of the capsule.

COAGULATION-TIME OF THE BLOOD.

A COMPARISON BETWEEN THE WRIGHT AND THE BRODIE–RUSSELL INSTRUMENTS, BASED UPON SIX HUNDRED OBSERVATIONS.

BY F. T. MURPHY, M.D., AND A. H. GOULD, M.D., BOSTON.
For the Division of Surgery of the Medical School of Harvard University.

THE coagulation-time of the blood is the interval which elapses between the moment of the withdrawal of the blood from the body and the moment when the blood coagulates. To determine this interval for clinical purposes, five methods are used: (1) The simplest procedure is still extensively employed, and requires merely that a drop of blood be placed upon a clean glass slide. The consistency of the blood is periodically tested by moving the drop with a needle. When the blood becomes gelatinous and fibrin shreds are thus demonstrable, coagulation has taken place. This is plainly crude technic. It cannot be relied upon to indicate a delayed coagulation, because of the rapid evaporation which occurs, upon subjecting the drop to the direct action of the air. (2) A decided improvement upon the old method just described is the microscopic examination of the blood. A fresh drop is placed upon a slide and covered with a cover glass. The blood is watched with the microscope until delicate fibrinous processes make their appearance. The recognition of the first shreds of fibrin is said to mark the end of the coagulation-time; but, since these shreds do not appear simultaneously in all parts of the drop, the method is inaccurate. (3) In the third method, described by Vierordt in 1878, a drop of blood is drawn into a capillary glass tube. A piece of horse hair, which has been properly cleaned, is inserted into the column of blood in the tube, and is moved up and down, at intervals. When the blood adheres to the hair, the moment of coagulation has come. The writers have had no success with this method and do not recommend its use.

In 1893 A. E. Wright constructed an apparatus, consisting of a number of similar, carefully calibrated, capillary tubes. A drop of blood drawn up into one of these tubes will adhere

to the lumen when coagulation takes place. The exact moment when this adhesion occurs is determined by moving the blood column from time to time. This is done by blowing gently into the tube. When no response to this air pressure can be obtained the column of blood is coagulated. Several observations are made in this manner upon blood taken at regular intervals. No reliable results were obtained, by attempting to judge of the degree of coagulation from the consistency of the column of blood when forcibly expressed from the end of the tube. It was at first thought necessary to protect the blood from changes in temperature by suspending the tubes against a water bath. This measure has been found to be superfluous, and now no particular effort is made to keep the blood at body temperature. The favorable results reported by Wright and others, in cases where this instrument was employed, led to its use by the writers. In this series of cases, an attempt has been made to find the simplest and most accurate instrument. For this purpose the Wright apparatus was compared with the (5) Brodie-Russell.

The last method to be described is a device of T. G. Brodie and A. E. Russell. Although introduced in 1897, it has not been so widely used as it merits. The original apparatus was furnished with a water bath to keep the moist chamber at body temperature, and with a stage to regulate the size of the drop, two features which made the apparatus complex and costly.

The modification devised by Prof. Guntzner and Dr. J. H. Pratt simplified the construction by omitting the water bath and stage without impairing the accuracy of the instrument. This modified apparatus was used by us.

The instrument is made by fastening a metal ring about 5 mm. in height and about 2 cm. in diameter to the surface of a glass slide. A hole in one side of the ring admits a small metal tube to which is attached a rubber tube and bulb, while, on the opposite side of the ring, is a second hole which provides for the escape of the air current. The end of the metal tube is bent slightly upward so that, by moving the cover glass, the air may be directed on the edge of the drop of blood. The upper edge of the ring is anointed with vaseline, and a drop of water placed in the chamber formed by the ring and the glass. A drop of blood is caught on a heavy cover glass and the latter placed

upon the ring so that the blood drop projects into the moist chamber. The vaseline prevents the entrance of air around the edge of the ring and holds the cover glass in place. The drop is now watched with a low power microscope, while a current of air is forced through the metal tube. In this manner the corpuscles are set in motion. At first the motion may be irregular, but soon a ring of serum separates at the edge and the whole drop rotates. As the end of the coagulation-time approaches translucent masses appear throughout the drop of blood. These masses increase rapidly in size, and about them coagulation seems to take place. The moment when the edge of the droop of blood fails to rotate in response to the air current marks the end of the coagulation-time. This phenomenon may take place slowly or suddenly. As a control in all cases the cover glass was removed and the blood drop pricked with the point of a needle. Demonstration of fibrin shreds was regarded as final evidence that coagulation had occurred.

The technical difficulties of the Brodie-Russell are fewer than those to be encountered when using the Wright instrument. If the drop whirls at all in the moist chamber, a practically accurate coagulation-time can be obtained. Occasionally the drop cannot be made to rotate by the air current. This is usually due to uncleanly technic, but is sometimes caused by the exposure of the drop to a cold draught.

The Wright tubes are cumbersome, easily broken, and difficult to clean. It is not possible to tell at once whether or not the preparation will be a successful one, as can be done with the Brodie-Russell. In a certain number of cases the blood will not coagulate at all. The failure of the blood column to adhere to the lumen of the Wright tube cannot always be explained. Although sometimes if the blood is moved, just as coagulation takes place, the serum collects around the outside of the clot, and an adhesion between the clot and the tube will never take place. This failure to adhere is the greatest imperfection in the method, because there is no way of determining the coagulation-time without moving the blood. From this and other causes the Wright instrument failed to give results in 15% of the observations, while the Brodie-Russell failed in less than 5%.

It is probable, as stated by physiologists, that the contact of the blood with the tissues outside the vessels causes, in some way, the elaboration of a fibrin ferment. If the needle prick is a deep one, the rapid flow of the blood will wash away the ferment and prevent immediate coagulation. The reverse is true of a superficial prick. It is obvious from this that the needle prick should be deep enough to cause a free flow of blood, and that only the first few drops of blood should be used.

In this series of 59 cases, we have used the Wright tubes and the Brodie-Russell moist chamber side by side. The experiments were done in open wards and in small rooms, at the Massachusetts General Hospital, where the temperature varied between 51.8 and 85 degrees Fahrenheit. The coagulation-time was not found to be influenced by the temperature within these limits. Six observations were made with each instrument on 42 of the cases. In the remaining cases, the scheme of 12 observations on each patient could not be carried out.

The surface of the skin was cleansed with soap, water and alcohol, and the glass instruments with water, ether and alcohol. The blood was drawn from the surface of the body in three places, namely: from the lobe of each ear and from the ball of a thumb, a large triangular needle being used for the puncture, to insure the free flow of blood.

There have been no marked differences between the coagulation-times of the blood-drops taken from different points on the surface of the body, provided the flow has been equally free, although the contrary was observed by Pratt. The writers are convinced, from numerous tests, that if several drops of blood are taken simultaneously from different points on the surface of their body, their coagulation-times will coincide, if the technic is perfect. Our results have not always shown the coagulation-times to be exactly the same when done with two instruments at the same time. The variations beyond a reasonable limit of error have been few, and might be explained by faults in technic. The average coagulation-time with the Brodie-Russell instrument in 300 observations was three minutes and twelve seconds; the average with the Wright was four minutes and eighteen seconds. This result is somewhat lower than that usually given.

Variations were found in health between one and seven minutes with both instruments. We attribute the extremes to technical errors. The limits are presumably three to six minutes. The proof of a delayed coagulation must be based on several observations, in order to minimize the influence of technical errors.

In this series are included 15 jaundice cases, the lesions of which embraced nearly every known cause of jaundice, *i. e.*, gallstones, catarrhal jaundice, cholecystitis, cirrhosis of the liver, cancer of the liver, cancer of the head of the pancreas, chronic pancreatitis, etc. It is of interest to note that in none of these cases did the coagulation-time vary from the normal.

The conclusions to be drawn from these observations are as follows:

The Brodie-Russell is more reliable than the Wright instrument.

The average coagulation-time is between three and six minutes.

The proof of a delayed coagulation must be based upon several observations.

The coagulation-time is not affected by the ordinary changes in room temperature.

Blood obtained simultaneously from different points on the surface of the body shows no marked variation in the coagulation-time.

A delayed coagulation is not constantly associated with jaundice due either to benign or to malignant obstruction.

[The writers are greatly indebted to the visiting Staff of the Massachusetts General Hospital for their courtesy in providing material for these observations.]

REFERENCES.

Vierordt, C. H.: Archiv f. Heilkunde, 1878, xix, p. 193.
Wright, A. E.: Brit. Med. Journ., July 29, 1893: Feb. 3, 1894.
Brodie, T. G., and Russell, A. E.: Journ. of Physiology, 1897, xxi, p. 403.
Pratt, J. H.: Journ. of Med. Research, Aug. 1903.

ENTEROSTOMY IN PERITONITIS

BY ROBERT B. GREENOUGH, M.D., BOSTON.

Surgeon to Out-Patients, Massachusetts General Hospital; Assistant in Surgery, Harvard Medical School.

For the Division of Surgery of the Medical School of Harvard University.

THE value of direct drainage of the intestine by enterostomy, in cases of acute intestinal obstruction, is so well recognized as to need no further argument in its support. It is almost universally employed in the graver cases of mechanical obstruction or "ileus," and the technique and indications for the operation have been thoroughly established. (Kocher,[10] Treves.[28])

The value of enterostomy in that form of intestinal obstruction which occurs in diffuse peritonitis, the so-called "dynamic obstruction" or "paralytic ileus," has not been so fully recognized. A number of writers have called attention to the advantages of the operation in this condition, but the varying technique of the application of the fistula, and the different arguments advanced in its support, appear to justify a brief review of the subject and the report of a series of forty-one cases of diffuse peritonitis from the Massachusetts General Hospital in which the operation has been done. The writer would here express his thanks to the surgeons of the hospital for the permission to report their cases.

In 1891, Mr. F. T. Paul[23] of Liverpool described a glass tube which he used in the operation of inguinal colostomy, and in 1892 he published a further communication in which he reported the use of this tube in cases of acute mechanical obstruction and peritonitis and in resection of the colon. The device was accepted in England and is in use in that country at the present time. In 1895, a similar device was described by Dr. S. J. Mixter[20] of Boston and its value in the paralytic obstruction of acute general peritonitis reported.

The Mixter tube and the Paul tube are to all intents and purposes the same, and although the priority of description belongs undoubtedly to Mr. Paul, to Dr. Mixter belongs the credit of its successful application in the treatment of paralytic obstruction and its introduction in this community, where it is commonly known as the Mixter tube.

In 1893, Henrotin [9] observed the beneficial effect of a spontaneous fecal fistula in a case of diffuse peritonitis and applied the principle successfully in a later operation for the same condition. Hadra [7] in 1894, Mixter [20] in 1895, Porter [25] in 1897, Pond [24] in 1898 and van Arsdale [29] in 1899 bore witness to the efficacy of the operation in paralytic obstruction and reported cases. During this time puncture or aspiration of the distended bowel at operation with immediate closure of the wound was extensively employed in cases of diffuse peritonitis. McCosh, [18] however, observed that the relief to distention obtained by this maneuvre was confined to a distance within twelve inches of the puncture, and in general the temporary and incomplete relief obtained by this method, and the inability to apply the procedure in the after treatment of the case, have led to its rejection in favor of the more lasting effects of enterostomy. In 1897 McCosh [18] advised the injection of magnesium sulphate solution directly into the small intestine at the time of operation, and reported a number of successful cases. This procedure again approaches that of enterostomy and has obtained a number of adherents. It is directed against the symptom of paralysis of peristalsis and has been combined with multiple puncture of the bowel and closure of the wounds. Its advantages and disadvantages will be discussed in connection with the causes of distention.

Lennander [14] in his valuable article on peritonitis published in 1901 discusses the value of puncture of the intestine and enterostomy and decides strongly in favor of the latter in the graver cases of diffuse infection. He opens the cecum in preference to the ileum, on account of the danger of irritation and digestion of the wound and the development of an artificial anus. The cecum is attached to the parietal peritoneum and a catheter is introduced and held in place by a purse-string suture. He considers the operation indicated

when distention is present or when its advent is to be feared from the extent of the peritoneal infection. When enterostomy is not performed at the primary operation Lennander advises the fixation of the cecum in the wound for secondary enterostomy if occasion should arise.

At the German Surgical Congress in 1902, Heidenhain [8] presented an elaborate paper on enterostomy in peritonitis and reported several cases. He considers that the obstruction in peritonitis is chiefly due to paralysis of peristalsis, but that this paralysis is to a great extent local in character and confined to one or more adjacent coils of bowel. The cause of the paralysis he attributes chiefly to infiltration of the bowel wall and to toxemia, although he admits the significance of adhesions and mechanical obstruction. For these reasons Heidenhain performs enterostomy of the ileum above the affected portion of the bowel and does not advise the operation when there is a diffuse infection of the peritoneal cavity. At the same meeting Doyen [3] of Paris presented a communication upon enterostomy of the jejunum in peritonitis, an operation against which a number of arguments can be advanced, based chiefly upon the need of an immediate secondary operation for closure of the fistula in order to prevent digestion of the wound and death from starvation.

In 1903, papers by Finney and Pancoast,[5] Follis,[6] Lund [15] and Escher [4] appeared on the subject of enterostomy in peritonitis and other conditions, and a number of methods of operation were described. Finney and Escher attached the opening in the bowel to the parietal peritoneum by suture and protected the abdominal cavity with gauze, while Follis placed gauze between the bowel and the parietal peritoneum and sutured through the gauze. Follis made use of the operation chiefly for mechanical obstruction and opened the ileum. Finney also opened the ileum for the relief of distention either of mechanical or paralytic origin and for the introduction of nourishment. Escher advises enterostomy especially in typhoid perforation, in order to save the time required to close the perforation and to ensure drainage of the intestine. Lund [15] considers especially cases of distention due to mechanical obstruction rather than paralysis, and occurring in local rather than diffuse infections of the peritoneum. He

advises secondary enterostomy of the ileum as the operation to be preferred. For this purpose the ileum is sutured to the parietal peritoneum and a catheter introduced for drainage. The fistula is then to be closed by excision and suture at a later operation. He reports in detail five cases of enterostomy of which four recovered, and refers briefly to five other unsuccessful cases which are not reported.

Statistics of results in diffuse peritonitis which are based upon selected cases can be of little value. So many factors enter into the question of the ultimate result of the disease that it is impossible to find two cases exactly alike. The duration of the disease and, what is of far more importance, the extent of diffusion which has occurred during that time, the source of the infection and its virulence, the presence or absence of gross or readily diffusible irritants accompanying the infection, the resistance of the patient and the previous condition of the peritoneum, all play an important part in the patient's chances of recovery. The operation itself, the duration of anesthesia, the extent of manipulation and exposure of the abdominal contents and the efficiency and rapidity of the surgeon are of great significance. Finally, the conduct of the after-treatment of the case, the judicious use of lavage of the stomach and bowel, the administration of fluids of stimulants and of nourishment, the employment of subcutaneous and intravenous infusion, and the care of the abdominal wounds and drainage wicks or tubes, — all are important elements in the results of treatment of this grave disease.

The classifications of the different forms of peritonitis are often inadequate in clinical application. The three forms of diffuse peritonitis described by Mikulicz [12]; diffuse septic, gangreno-purulent and fibrino-purulent peritonitis can in many cases be differentiated with certainty only at the autopsy table. For clinical purposes the main fact is the determination of whether the peritonitis is a local process or whether it is diffuse and spreading. The appearance of the exudate and of the peritoneum, the extent and rapidity of diffusion and the constitutional reaction of the patient then determine the gravity of the condition. In this connection the correct interpretation of the appearances of the perito-

neum of the general cavity in the presence of a local process is of great importance. In certain cases of local peritonitis of a virulent type a degree of inflammatory reaction occurs in the general peritoneal cavity which is due more to chemical and toxic causes than to actual bacterial infection. This condition produces a moderate injection of the peritoneum and a serous exudate containing leucocytes. It has been called "peritonism" by many writers (Burkhardt,[2] Weber [30]) and it subsides promptly on evacuation of the local abscess without requiring irrigation or drainage for its relief. While undoubtedly predisposing to a more severe form of actual peritonitis on the introduction of bacteria, peritonism itself is of minor significance and should be distinguished from actual peritonitis. Without the proof of cultures or cover-glass examination, therefore, the lesser degrees of peritoneal inflammation cannot always be accepted as demanding more than local treatment.

The actual causes of death in diffuse peritonitis are variable. Patients may die in the first twenty-four hours after operation from the severity of the disease and the added shock of operation. A certain number of cases will die within forty-eight hours from the commencement of the disease itself with septic intoxication (the peritoneal sepsis of Mikulicz), whether operation is done or not. Other cases succumb from the second to the fifth day of the disease with "peritoneal facies," vomiting, paralysis of the bowel, distention, low temperature and thready pulse, a train of symptoms largely due to the suspension of peristalsis and in part remediable by enterostomy.

A certain number of cases survive this stage of the disease only to die of sepsis or exhaustion from the extent of the local suppurative process in the peritoneal cavity, after the diffuse peritonitis has subsided and peristalsis has been again established. Among this number are the cases of subdiaphragmatic and pelvic abscess, which occur after purulent peritonitis.

Finally, cases may die of intercurrent diseases or later complications in convalescence. Pneumonia, uremia, pylephlebitis and thrombosis, liver abscess and the various forms of postoperative intestinal obstruction due to adhesions, — each cause a certain number of deaths after diffuse peritonitis.

The tympanites of peritonitis has been attributed to a number of different causes, and a brief review of the subject is necessary in the consideration of the value of enterostomy. An increase in the amount of gas in the intestine in peritonitis may be due to increased production, diminished outflow or diminished absorption. Diminished out-flow is chiefly due to mechanical obstruction of the lumen of the gut, or to diminished or suspended peristalsis.

A sudden and severe irritation or stimulation of the sensory nerves of the abdominal area is capable of causing a reflex inhibition of peristalsis. This occurs in cases of biliary and renal colic (Nothnagel [21]) and is probably the main cause of the suspension of peristalsis which occurs so frequently after laparotomy. This inhibition paralysis is undoubtedly a conservative effort on the part of Nature. It is certain that active peristalsis greatly favors the rapidity of diffusion of an infecting agent in the peritoneal cavity (Meisel [19]), and absence of peristalsis would tend to limit diffusion and confine the process to a local infection. This theory has its clinical application in the non-operative treatment of appendicitis during the intermediate stages, which has been advocated by Ochsner.

Another form of paralysis of peristalsis has been thought to be due to septic absorption. The toxins of a virulent infection, either within the bowel or in the peritoneal cavity, may act locally upon the nerve endings and muscle fibers of the intestinal wall or through the central nervous system. The tympanites of typhoid fever is advanced by Nothnagel [21] as a type of toxic paralysis of peristalsis.

Paralysis of the muscular action of the intestine has also been attributed to the local effect of infiltration of the intestinal wall by inflammatory products. (Heidenhain,[8] Nothnagel.[21]) Marked examples of this condition are seen occasionally after strangulated hernia and in the intestine forming the wall of an appendix abscess. It has been thought to occur also in diffuse peritonitis, but its importance is probably far greater in inflammatory conditions of a local nature.

Pure mechanical obstruction of the bowel is found to be present in a certain number of cases of diffuse peritonitis. This is especially the case when the peritonitis results from

mechanical obstruction or when a local inflammatory process antedates by some time the onset of the diffuse infection. Compression of the bowel by inflammatory exudate may occur as in a pelvic abscess of large extent. Obstruction by bands and adhesions from a previous peritonitis are occasionally reported. The loss of peristalsis by the adhesion of large areas of bowel to the abdominal wound may offer impediment to peristalsis, and twists and kinks of the coil of bowel immediately above the adhesion may close the lumen of the bowel and cause obstruction. Obstruction of the bowel by gauze wicks which have been introduced for drainage is also to be borne in mind as one of the possible causes of mechanical obstruction. The symptoms of intestinal obstruction due to mechanical causes, however, develop as a rule only after the lapse of a period of time sufficient for the formation of firm adhesions. Distention due to obstruction of this nature appears during the convalescence from operation in diffuse peritonitis, or in cases in which a local inflammatory process has existed for some time prior to the appearance of the symptoms of diffuse infection. Much has been written upon the subject of intestinal obstruction of this nature and its relief by operation. An increase of peristaltic activity can often be demonstrated in these cases by visible waves of contraction in the distended bowel, accompanied by colicky pain of an intermittent character. This condition is very different from the absence of peristalsis in the distention of peritonitis. The records of the Massachusetts General Hospital from 1900 to 1904 show 17 cases of acute intestinal obstruction after inflammatory conditions of the peritoneum, which came to operation. Seven cases of more chronic obstruction were also found attributable to this cause. The shortest period of time which elapsed in any case between the first symptoms of peritonitis and the operation for obstruction was six days. This was a case of local appendix abscess of two days' duration which was operated upon by Dr. Codman. Four days later symptoms of mechanical obstruction demanded interference, and a coil of ileum was found twisted upon itself and adherent to the appendix wound. The adhesions were freed, a Mixter tube was tied into the distended coil of ileum and the patient recovered. A secondary

operation for closure of the fistula was necessary and the patient is now well. Six cases showed obstruction between seven and fourteen days after the first symptom of peritonitis and 11 cases only after the lapse of a period of time greater than one month. The cause of the mechanical obstruction in these cases was as follows: Volvulus occurred twice, twists and kinks four times and bands and adhesions in 11 cases. In two cases only was the obstruction the result of a diffuse peritonitis, whereas in 16 cases it followed a local inflammatory process in the peritoneal cavity. Of the 24 cases of diffuse peritonitis which are reported in detail at the conclusion of this paper and in which enterostomy was done as a primary operation, distention was present at the time of operation in 16 cases. Of these 16 cases, in 9 adhesions were found in some portion of the peritoneal cavity, in 3 cases the record is not specific on this point and in 6 cases no adhesions whatever were discovered. In only two cases of the entire 24 was actual mechanical obstruction present; this was due in one case to cancer of the colon and in the other to an abscess in the pelvis. The duration of the diffuse peritonitis in these cases averaged 2.4 days from onset to operation. It is apparent, then, that obstruction due to purely mechanical causes occurs chiefly after the lapse of a considerable time from the beginning of the peritonitis and that it is favored more by a local than by a diffuse form of infection. Visible peristalsis and colicky pain are not infrequently observed in the early stages of mechanical obstruction and serve to distinguish from the paralysis of peristalsis which accompanies diffuse peritonitis.

An important cause of paralysis of peristalsis, and probably in the later stages of peritonitis and of intestinal obstruction, the most important one, is distention of the bowel by the accumulation of gases within its lumen. The growth of the bacteria which normally inhabit the intestinal canal results in the production of gases of different varieties as by-products in the decomposition of the intestinal contents. (Kukula.[13]) When the out-flow of these gases is prevented, distention of the bowel ensues, the stagnant intestinal contents undergo more rapid decomposition, and the gases, ptomaines and bacterial toxins which accumulate affect the integrity and

function of the bowel wall. Up to a certain point distention of the intestine may occur without permanent effect; beyond this point, however, the thinning of the intestinal wall and interference with its blood supply and nervous mechanism produce a condition of paralysis of the muscular coats of the intestine. Recovery from this condition is of necessity slow and may not occur at all. Examples of paralysis from over-dilatation are familiar in the stretched cervix or sphincter ani or the over-distended bladder. In over-distention of the intestine we thus have the familiar conception of the vicious circle in another form; more gas, more distention, more paralysis, more decomposition, more gas, etc. It is this aspect of distention against which enterostomy offers most satisfactory relief. Paralysis of the intestinal muscle, however, is not the only danger of obstruction to the onflow of the intestinal contents. Ptomaines and bacterial toxins are produced in the process of decomposition, and their absorption is followed by grave systemic disturbance. The absorption of these products is probably delayed by the disturbance of circulation in the distended bowel, but that it does occur is proved by the constitutional toxemia of strangulated hernia, and by the experiments upon animals which have been reported. (Kukula,[13] Borszczky.[1]) The thinning of the intestinal wall which results from the accumulation of gases is accompanied by a change in its physical characteristics of such a nature as to allow the ready passage of bacteria from the lumen of the bowel into the blood vessels, and even through the wall into the peritoneal cavity. (Borszczky and Generisch.[1]) The significance of this phenomenon in the increase in virulence of a case of peritonitis, and even in the production of a fatal septicemia, is readily appreciated.

Although in theory the different causes of intestinal paralysis and obstruction can be differentiated and discussed, in actual occurrence they merge one into another to such an extent that they can be separated with difficulty or not at all. Schlange[26] distinguishes two main classes of intestinal obstruction, mechanical and "dynamic." Mechanical obstruction is associated especially with local and chronic forms of peritonitis, and dynamic or "paralytic ileus" with acute, diffuse forms of the disease However true this distinction

may be in the early stages of both conditions, it is a well recognized fact that the distinction fails as the disease progresses to its fatal termination. In pure mechanical obstruction, due to a constricting band, the over dilatation and toxic paralysis produced by decomposition of the intestinal contents may prevent recovery after removal of the constricting band by operation, or the symptoms of diffuse peritonitis may supervene and mask the original symptoms of intestinal obstruction. In diffuse peritonitis the process may be even more complicated. The inhibition of peristalsis from the irritation of the primary infection merges into the paralysis of toxemia as rapid absorption from the peritoneal cavity takes place. To this is further added the paralysis from over dilatation as gases collect from the fermenting contents of the intestine. The extent to which actual mechanical causes enter into the production of the dynamic obstruction of peritonitis has been much discussed. Körte [12] considers that infiltration of the bowel wall plays an important part in paralytic obstruction, and Kocher [10] believes that slight mechanical causes, such as light adhesions, circulatory changes and the handling of the intestine at operation, are important factors. In all probability many causes enter into the production of the condition, but it must be admitted that to a paretic intestine a mechanical obstacle of almost trivial nature may be insurmountable. The main feature of the distinction, however, hangs upon the presence or absence of peristalsis. When peristalsis is present, as shown by visible contractions and spasmodic pain, mechanical causes are especially to be considered. When pain is continuous and no evidence of peristalsis is to be obtained, the graver condition is to be feared and relief must be prompt or not at all.

The more remote effects of accumulation of gas in the intestine are next to be considered. The distended coils of bowel demand more room for their accommodation, which can be obtained only by elevation of the abdominal wall and of the diaphragm. Embarrassment of respiration and even of the action of the heart are not uncommonly observed as a result of this encroachment upon the cavity of the thorax. Another result of paralysis of peristalsis is the increased opportunity for the formation of adhesions between the

coils, with the subsequent danger of mechanical obstruction. At the time of operation distended coils may so obstruct the view or the manipulations of the surgeon as to endanger life by prolonging or rendering inadequate the measures for the relief of the disease. Finally, the normal elimination of fecal material and gases by rectum is prevented by suspension of peristalsis, and the normal absorption of fluids and of nourishment by the stomach is interfered with by the vomiting which accompanies obstruction of the intestine.

Against the dangers of suspension of peristalsis in peritonitis there remains to be contrasted only its possible conservative effect in limiting diffusion of the process throughout the general peritoneal cavity. That inhibition of peristalsis is in fact a conservative phenomenon is hardly open to doubt. The occasional success of the opium treatment in cases of diffuse peritonitis before the days of operation attests the correctness of this view, and the Ochsner[22] treatment of appendicitis is based upon this theory. It is not the purpose of this paper to discuss the Ochsner treatment, and it has not been given sufficient trial at the Massachusetts General Hospital to admit of a report upon its value. In fact, so radical a departure from existing tenets of surgical faith requires time for its acceptance. The dangers of delay in cases which ultimately demand operation and the possibility of error in diagnosis have worked against its general adoption. Cases of peritonitis which are beginning to spread from a local point of origin, such as the appendix, and in which the general cavity presents the condition spoken of above as peritonism rather than peritonitis, can probably be aided toward local limitation by the Ochsner method. Cases, however, in which the greater portion of the peritoneal cavity is already infected, and especially those cases in which a constant source of infection, such as a perforated gastric ulcer or a ruptured appendix abscess, is continually supplying further contaminating material in large amount, the value of the conservative inhibition of peristalsis disappears in the dangers by which it is accompanied,— the dangers of distention, paralysis, toxemia, septicemia and of mechanical hindrance to respiration and circulation.

The advantages of enterostomy in peritonitis are in the

main the avoidance of the dangers of distention, by the removal of the decomposing contents of the intestine. The muscular wall of the bowel is enabled to regain its tone and to resume its suspended function. The absorption of ptomaines and bacterial toxins from the intestinal mucosa and their poisonous effects upon the patient are diminished. The escape of bacteria from the intestinal canal into the peritoneal cavity and into the circulation is diminished if not prevented. Pressure upon the diaphragm is relieved and the attendant disturbance to respiration and circulation. In addition to these direct results of enterostomy, however, the surgeon obtains a direct control over the intestine which may be employed to great advantage. Lavage of the bowel through the enterostomy wound promotes the discharge of intestinal contents from far beyond the immediate vicinity of the fistula. A most important aspect of the enterostomy opening is that emphasized by Finney in the statement that it should be regarded "more as a mouth than as an anus." Stimulation, fluids and nourishment may be introduced directly into the portion of the bowel where they are most rapidly absorbed, and where they cannot be immediately rejected by vomiting or by an involuntary dejection. By this means the function of the kidneys may be sustained and the constitutional reaction against the disease supported.

A further advantage of enterostomy which has been noted by many writers is the possibility of the direct introduction of cathartics into the intestine. When a fistula is made, however, lavage of the bowel will be found to supplant the cathartic treatment of peritonitis after operation to a great extent. The reflex inhibition of peristalsis above described and the tendency to paralysis of peristalsis from distention explain the inefficacy of cathartics introduced directly into the bowel at the time of operation in the graver forms of peritonitis. When peristalsis is capable of being excited by magnesium sulphate, its introduction at the time of operation, in the manner advocated by McCosh,[18] produces satisfactory results. When paralysis is present, however, and peristalsis cannot be excited by the irritation of the cathartic, its introduction can have only a toxic effect upon the patient and increase the intestinal irritation and decomposition. During

the first twenty-four hours after operation lavage of the bowel is to be preferred. After that time, if spontaneous action does not occur, the use of cathartics introduced through the fistula is generally followed by prompt results.

The disadvantages of an enterostomy are next to be considered and their importance weighed. A fecal fistula is an unnatural condition, extremely revolting to the patient and his attendants and acompanied by dangers of its own. To make a wound in the intestine and insert a Mixter tube prolongs the operation for a few moments, at least, and where every moment under the anesthetic is of importance even this should not be done without its benefit to the patient being well established. After the operation the presence of the enterostomy opening makes the dressings more complicated, and when the fistula is established by the removal of the tube, more frequent and more offensive. The danger of contamination of the peritoneal cavity from the enterostomy wound, before adhesions are established is not to be considered when the Mixter tube is used. After its removal, however, soiling of the wound and continued suppuration must be guarded against by frequent dressings and scrupulous cleanliness. The danger of persistance of the fistula depends largely upon the situation and method of its formation. An opening in the jejunum will rarely close spontaneously on account of the irritating character of the intestinal secretions. Openings in the ileum are less significant in this respect and in the cecum least of all. The nature of the opening in the bowel, whether it is transverse or longitudinal to the long axis, whether it comprises a large or a small portion of the circumference of the intestine, and whether it is above or below the parietal peritoneum, — all are factors which exert an influence upon spontaneous closure. In general it may be said that an opening in the cecum, made by an incision in the long axis of the bowel not more than one-half inch long, and prevented from elevation above the line of the parietal peritoneum, will almost always close spontaneously. In other cases the persistence of the fistula will demand its closure by operative measures, a serious drawback to the value of enterostomy. Finally, it may be urged that the presence of a fecal fistula increases the adhesions which remain

after the peritonitis and predisposes to hernia and to intestinal obstruction. The dangers and disadvantages of enterostomy are thus of sufficient weight to demand consideration before the operation is adopted. It is obvious also that enterostomy can exert little effect upon certain of the causes of death from peritonitis. The cases which die in the first twenty-four hours after operation, whether from the shock of operation or from the septic intoxication of the disease, can be expected to obtain little benefit from enterostomy except that their last hours may be made more comfortable and their distressing vomiting relieved. The cases which survive the operation and recover from the general infection of the peritoneal cavity, only to die of local sepsis and exhaustion or by one of the intercurrent complications, cannot be saved by enterostomy, however much they may have been benefited by the operation in the early stages of their disease. The intermediate cases, however, which ordinarily die from two to five days after operation, with distention, vomiting, low temperature and thready pulse, are the cases which obtain the most marked benefit from enterostomy. In these cases drainage of the bowel reduces the toxemia and relieves the distention, allowing the paralyzed muscles of the intestinal wall to regain their tone and peristalsis to be again established. In such cases the more remote dangers and disadvantages of a fecal fistula are not to be compared with the immediate and positive advantages to be obtained. It is to be regretted that the cases of this nature cannot be selected at the operation, but except within broad limits this does not appear to be possible at the present time. These considerations would appear to justify the performance of enterostomy as a secondary operation. A review of the statistics of secondary operations, however, makes obvious the fact that they have been performed as a rule too late to be of benefit. Diffuse peritonitis is a disease which is measured in hours rather than in days, and delay in waiting for the failure of enemata and cathartics to establish an indication for interference is fatal for the success of the enterostomy when it is performed. Cases of mechanical obstruction due to adhesions which develop in the course of the convalescence from peritonitis demand interference only when the indications are

well established, and in these cases, as advised by Lund, a secondary enterostomy is indicated, especially when the cause of the mechanical obstruction cannot be removed by an open operation. The portion of the bowel immediately above the obstruction is the situation to be chosen for opening under these conditions, and secondary closure of the fistula will then be necessary as a rule. In cases of diffuse peritonitis, however, which involve the greater portion of the peritoneal cavity, and especially where paralytic distention is present and no mechanical cause for the obstruction is found, a primary enterostomy is indicated, and for this purpose the cecum is to be preferred. Under these circumstances the mortality of cases of peritonitis treated by enterostomy will still be high, but a certain number of cases will be saved which would otherwise go on to a fatal termination.

The technique of enterostomy is extremely simple The Mixter tube is a bent glass tube of about ½ inch diameter, provided with a flange and collar about ¼ inch apart at the lower end. (Fig. 1.) A purse-string stitch is introduced in the intestine and in its center a linear incision ½ inch in length is made parallel with the long axis of the bowel. In the large

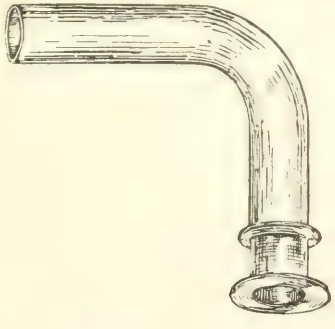

Fig. 1. Mixter tube for enterostomy of cecum. Actual size, about ½ inch in diameter.

intestine the incision should be in the center of one of the longitudinal bands. The flanged end of the tube is inserted into the bowel and the purse-string stitch is tied under the collar, thus preventing leakage and securing the tube from slipping in or out. The end of the purse-string stitch is

then carried through the parietal peritoneum just below the margin of the abdominal wound and the opening in the bowel is thus secured below the level of the abdominal wall. (Fig. 2.)

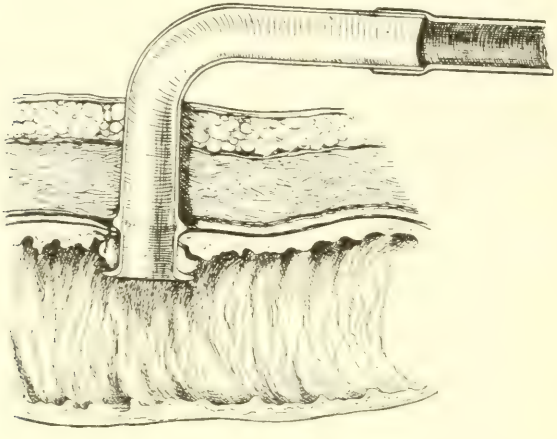

FIG. 2. Diagram of Mixter tube in situ, showing purse-string suture and fixation to parietal peritoneum below abdominal wall. Drawings by Miss Florence Byrnes.

The wound is now dressed in the customary manner and a rubber tube attached to the outer end of the glass tube and conducted through the dressings to a receptacle beside the bed. The chief advantage of the Mixter tube over other methods of enterostomy is the fact that immediate opening of the bowel is obtained without the risk of contamination of the general peritoneal cavity before the necessary time has elapsed for the formation of protective adhesions. The flange and collar also prevent the tube from slipping too far in or too far out of the bowel, an accident which is not infrequent when a rubber tube or catheter is used. Another advantage of hardly less importance is the fact that the fistula remaining after a Mixter tube enterostomy is below the parietal peritoneum and closes spontaneously in many cases. Tubes of varying weight and size are provided to suit the size of the intestine which is to be opened, and a lighter tube than the one described is advisable for introduction in the small intestine. The purse-string stitch cuts out as a rule from the fourth to the seventh day and the tube comes away. After this has occurred the fistula must be treated

by frequent irrigation and its closure promoted by drawing together the edges of the wound. Secondary suture of the fistula in the wound is frequently successful, and if the indications for immediate closure are sufficient, anastomosis or resection may be done. Resection was not necessary in any of the cases here reported. The selection of the cecum rather than the ileum or jejunum for enterostomy has been widely discussed. The jejunum appears to be ill adapted to the purpose for a number of reasons, owing to the facts that the jejunal secretions are extremely irritating to the wound, that the drainage is too high to be effective, that death from inanition threatens unless nutrition is artificially maintained, and that immediate closure of the fistula by operation is attended by a high mortality. Between the ileum and the cecum no such potent reasons enter into the decision and it is more a matter of the indications of the special case. In cases of diffuse peritonitis, where mechanical causes for obstruction are not found, as a rule the cecum is to be preferred. Paralytic distention affects the large more readily than the small intestine because of its thinner wall. The fistula in the cecum drains the ileum to a certain extent, whereas drainage of the ileum does not affect the cecum. The fistula in the cecum is less irritating, does not affect nutrition and generally closes spontaneously without operative interference. Its lateral situation also makes later mechanical obstruction from adhesions less probable than when the ileum is attached to the abdominal wall.

Forty-one cases of diffuse peritonitis were treated by enterostomy in addition to other operative measures, at the Massachusetts General Hospital between January, 1900, and March, 1904. In 24 cases enterostomy was done at the first operation and of this number 5 cases recovered, 21%. In 17 cases it was done as a secondary operation, generally when the patient was moribund, and only one case recovered. The technique of operation employed for the diffuse peritonitis is detailed in the abstract of cases, but it may be said that multiple incision, irrigation with salt solution and drainage were employed in the majority of cases. No case that was not actually moribund was refused the possible benefit of operation.

Of the 24 cases of diffuse peritonitis in which primary enterostomy was done, 17 were due to appendicitis and one each to the following causes: cancer of colon with perforation, pancreatitis, perforation of gastric ulcer, stab wound of intestine, cholecystitis, typhoid perforation and post-operative peritonitis. Of the 17 cases of secondary enterostomy 10 were due to appendicitis and one each to the following causes: cancer of colon with perforation, rupture of intestine, pyo-salpinx, perforation of gastric ulcer, perforation of duodenal ulcer, stab wound of intestine and post-operative peritonitis.

Of the 24 cases of primary enterostomy, 19 died. Eleven of this number, 58%, died within twenty-four hours, 2 in the second day, 2 in the third day, and 4 after more than four days had elapsed, on the fifth, sixth, twelfth and thirteenth days. The actual cause of death in the last four cases was determined at autopsy in three instances. One case was due to pancreatitis and diabetes with no further evidence of peritonitis, one to acute fibrinous peritonitis without free pus but with a gangrenous local abscess in the pelvis, and another to a local peritoneal abscess without general infection or distention. In the fourth case no autopsy was obtainable, but death occurred on the thirteenth day after operation and was apparently due to a local abscess in the pelvis. The symptoms of diffuse peritonitis had subsided and peristalsis was well established. In each of these four cases benefit was obtained from the enterostomy, although a fatal result of the disease was not prevented. Of the 19 cases which died 4 only are left as having died on the second, third and fourth day after operation, or 21%. Of the 16 cases of secondary enterostomy which died, one died within twenty-four hours of the first operation, 8 on the second, third and fourth days, 50%, and 7 after the fourth day. In this connection the statistics recently collected by Dr. W. C. Quinby of Boston are of interest. Of 81 cases of undoubted diffuse peritonitis after appendicitis at the Massachusetts General Hospital, 57 cases died, 70%. Of this number, the deaths on the first day after operation were 29%, on the second, third and fourth days after operation, 31%, and after four days, 40%. These figures emphasize two facts in con-

nection with primary enterostomy. The operation has been done only in the graver cases of peritonitis, as shown by the number of cases which died within twenty-four hours, 58% against the 29% of all cases collected by Dr. Quinby. The number of cases dying on the third, second, and fourth days is also reduced by enterostomy from 50 and 31% to 21%. It is to be noted therefore that in spite of the fact that enterostomy has been done as a primary operation only in the graver cases of peritonitis, the mortality of the second, third and fourth days has been notably diminished. Under these circumstances the operation must be accorded a place as a measure of value in cases of grave diffuse peritonitis.

Five cases recovered after primary enterostomy. In four of these cases the peritonitis was due to appendicitis. The process in each case was diffuse throughout the abdominal cavity so far as could be ascertained by multiple incisions, and cultures showed the colon bacillus in three cases and streptococci in the fourth. The fifth case was due to perforation of a gastric ulcer which had occurred about six and one-half hours previously, and a diffuse peritonitis, with turbid serum and fibrin, was found over all the accessible portions of the abdominal cavity. In this case cultures were negative with regard to the presence of bacteria. No anærobic cultures were made, however, and proof of the presence of bacteria by cover-glass examination of the fluid was not attempted. In all five cases the severity and extent of the infection of the peritoneal cavity were such as to lead the surgeon operating to the belief that the usual operative measures would not be sufficient to ward off a fatal termination. That five such cases recovered would alone appear to justify the operation. In four of these cases the cecum was opened. One closed spontaneously on the eighth day, one on the seventeenth day and one after six weeks. One case was closed by a purse-string suture on the fifth day and never leaked. In the fifth case the ileum was opened and the fistula discharged slightly for ten weeks before closing spontaneously. In the one case of secondary enterostomy which recovered, the fistula was successfully closed on the fourteenth day by a purse-string stitch.

To sum up the points covered in this paper it may be said:

(1) The obstruction of the intestine in diffuse peritonitis is the result of a combination of causes.

(2) The most important cause is suspension or paralysis of peristalsis.

(3) Paralysis of peristalsis is due to inhibition, to toxic paralysis and to the paralysis of distention.

(4) Mechanical causes such as infiltration of the bowel wall and light adhesions in certain cases contribute to this paralysis.

(5) Pure mechanical obstruction due to adhesions is the result of chronic or local peritonitis of at least some days' duration.

(6) Enterostomy is indicated in addition to other operative measures in the graver forms of diffuse peritonitis.

(7) Its greatest advantage is the drainage of the gases and decomposing contents of the bowel and the relief of paralysis of peristalsis.

(8) By enterostomy the surgeon obtains direct control over the intestine for lavage and for the introduction of stimulants, nourishment, fluids and cathartics.

(9) For the relief of paralysis of peristalsis primary enterostomy is to be preferred to the secondary operation.

(10) Enterostomy is best performed by the use of the Mixter tube.

(11) The cecum is the most satisfactory part of the bowel for a primary enterostomy, and the jejunum is to be avoided.

(12) Spontaneous closure of the fistula may be expected when the cecum is opened, if the opening is kept below the level of the parietal peritoneum.

(13) By the systematic use of enterostomy in the graver forms of diffuse peritonitis the number of patients dying on the second, third and fourth days after operation is reduced.

(14) The symptoms of visible peristalsis and spasmodic pain in intestinal obstruction indicate a mechanical cause for the obstruction.

(15) The persistence of these symptoms, unrelieved by enemata and cathartics, is an indication for operation.

(16) Under these circumstances the cause of the obstruction should be removed if possible by operation.

(17) In advanced cases of obstruction of this form enterostomy of the coil of intestine nearest above the obstruction should be done.

ABSTRACT OF CASES.

PRIMARY ENTEROSTOMY.

1. Dr. C. A. Porter, 1902; age forty-five, pancreatitis, diabetes, peritonitis, seven days' duration, pulse 110, respiration 30, temperature 100.6, whites 34,000, tympanites; 2 incisions, irrigation, Mixter tube in descending colon, drainage, purulent bloody exudate in pelvis and between coils; culture streptococcus and bacillus mucos. caps. Died in five days. Autopsy, no general peritonitis, adhesions, abscess in pelvis, pneumonia, chronic pancreatitis.

2. Dr. C. A. Porter, 1901; age twenty-three, appendicitis, peritonitis, four days' duration (?), pulse 100, respiration 34, temperature 100.4, whites 16,000, tympanites; 2 incisions, irrigation, Mixter tube in cecum, appendectomy, drainage, sero-pus in right and left flanks and pelvis and between coils; streptococci. Recovery; no fecal discharge after tube removed on eighth day.

3. Dr. C. A. Porter, 1901, age twenty-six, appendicitis, peritonitis, four days' duration, pulse 150, respiration 30, temperature 104, no tympanites; 2 incisions, irrigation, appendectomy, Mixter tube in cecum, drainage, thick pus in flanks and pelvis and between coils; colon bacillus; magnesium sulphate given through fistula. Died twelve hours. No autopsy.

4. Dr. E. A. Codman, 1902; age ten, appendicitis peritonitis, two days' duration, pulse 140, respiration 24, temperature 101.6, whites 19,000, tympanites; 2 incisions, irrigation, appendectomy, catheter tied in cecum, drainage; foul pus right flank, purulent fluid left side, pelvis and between coils. Lavage and catharsis by fistula. Died in ten hours. No autopsy. The catheter was introduced in the cecum in this case by Kaders method for gastrostomy.

5. Dr. C. A. Porter, 1902; age twenty-two, stab wound of colon, five days' duration, pulse 100, respiration 25, temperature 101, whites 15,000, tympanites; one incision, irrigation, Mixter tube in descending colon, drainage; turbid fluid in left flank and pelvis, no culture. Lavage and nourishment by fistula. Died six days later. Autopsy, fibrinous peritonitis, no free pus, abscess in pelvis.

6. Dr. E. A. Codman; 1901, age five, appendicitis, peritonitis, four days' duration, pulse 180, respiration (?), temperature 107, tympanites; one incision, irrigation, two Mixter tubes in ileum at and above ileocecal valve, drainage; pus throughout, no culture. Died in two hours. No autopsy.

7. Dr. E. A. Codman, 1901; age fifty-three, cholecystitis; peritonitis, two days' duration, pulse 138, respiration 26, temperature 104, whites 21,000, tympanites; one incision, irrigation, Mixter tube

in cecum, drainage, pus throughout; colon bacillus; lavage of bowel and cathartics introduced by fistula. Died in twelve hours. No autopsy.

8. Dr. E. A. Codman, 1901; age thirty-seven, appendicitis peritonitis, four days' duration, pulse 104, respiration 30, temperature 103, whites 4,800, tympanites; 2 incisions, irrigation, 2 Mixter tubes, in ileum and in cecum, drainage; pus throughout; colon bacillus; salt solution and cathartics by fistula. Died in forty-eight hours. No autopsy.

9. Dr. S. J. Mixter; 1902, age nineteen, appendicitis, peritonitis, duration (?), pulse 100, respiration 20, temperature 98.6, whites 15,000, no tympanites; one incision, irrigation, appendectomy, tube in cecum, drainage; pus in right and left flank, pelvis and between coils; colon bacillus; salt solution and cathartics by fistula. Recovery; fistula closed on fifth day by purse-string, no leakage.

10. Dr. R. B. Greenough, 1902; age twenty-three, appendicitis, peritonitis, one day's duration, pulse 100, respiration 35, temperature 103, whites 11,000, tympanities; 2 incisons, irrigation, Mixter tube in cecum, drainage; cloudy serum throughout; colon bacillus; lavage, and catharsis by fistula. Recovery; attacks of hypogastric distention in convalescence relieved by lavage of colon by fistula, fistula closed spontaneously in six weeks.

11. Dr. R. B. Greenough, 1902; age six, appendicitis, peritonitis, two days' duration, pulse 150, respiration 50, temperature 103.8, whites 10,600, tympanites; 2 incisions, irrigation, appendectomy, Mixter tube in cecum, drainage; pus throughout; colon bacilli. Died in twelve hours. No autopsy.

12. Dr. R. B. Greenough, 1902; age twenty-one, perforation of gastric ulcer, peritonitis, six and a half hours' duration, pulse 100, respiration 30, temperature 101, whites 21,000, tympanites; 3 incisions, ulcer closed by suture, posterior gastro-enterostomy by McGraw ligature, irrigation, Mixter tube in cecum, drainage; turbid serum throughout; culture negative; fistula used for drainage and catharsis, no distention after lavage on second day, fistula closed spontaneously on seventeenth day. Recovery.

13. Dr. G. W. W. Brewster, 1900; age forty-seven, appendicitis, peritonitis, four days' duration, pulse 140, temperature 101, no white count, tympanites; one incision, no irrigation, Mixter tube in ileum, drainage; pus throughout; culture mixed growth, cocci and bacilli. Died in three hours. No autopsy.

14. Dr. Farrar Cobb, 1902; age sixty-three, perforation above cancer of colon, peritonitis, three hours' duration, pulse 110, respiration 32, temperature 100, whites 9,000, tympanites; one incision,

irrigation, Mixter tube in perforation of colon, drainage, fluid feces throughout peritoneal cavity. Died in ten hours. Autopsy, general fibrino-purulent peritonitis and cancer.

15. Dr. J. C. Warren, 1903; age forty-two, appendicitis, peritonitis, two days' duration, pulse 120, respiration 30, temperature 102, whites 25,000, tympanites; one incision, irrigation, Mixter tube in cecum, appendectomy, drainage; pus throughout; no cultures; fistula used for drainage, lavage and catharsis, no further distention. Died in twelve days. Autopsy, large local abscess in central portion of peritoneal cavity.

16. Dr. R. B. Greenough, 1903; age twenty-seven, appendicitis, peritonitis, six and a half hours' duration, pulse 95, respiration 20, temperature 99.3, no white count, no tympanites; 2 incisions, irrigation, appendectomy, drainage, Mixter tube in ileum, turbid serum in right and left flank, pelvis and between coils; culture colon bacillus. Recovery. Much discharge from fistula, lavage of bowel, no distention, fistula closed spontaneously in ten weeks.

17. Dr. J. G. Mumford, 1903; age fifty-nine, appendicitis, peritonitis, thirty-six hours' duration, pulse 136, respiration 45, temperature 103, whites 21,000, tympanites; one incision, irrigation, Mixter tube in cecum, drainage; pus throughout; colon bacillus. Died in eight hours. No autopsy.

18. Dr. G. W. W. Brewster, 1903; age sixty-four, diffuse peritonitis after operation for resection of colon for cancer with lateral McGraw anastomosis, duration forty-eight hours, pulse 120, respiration 24, temperature 101, no white count, tympanites; operation for peritonitis by 2 incisions, irrigation, 2 Mixter tubes in ileum and in cecum, drainage; pus throughout; no cultures. Died in ten hours. Autopsy showed diffuse purulent peritonitis due to leakage from end of bowel closed by purse-string.

19. Dr. F. B. Harrington, 1903; age forty-three, appendicitis, peritonitis, four days' duration, pulse 120, respiration 34, temperature 100, whites 10,000, tympanites; 2 incisions, irrigation, appendectomy, Mixter tube in cecum, drainage; pus throughout; no culture; fistula used for lavage, drainage and stimulation by hot salt solution every two hours; no vomiting, delirium and sepsis. Died two and one-half days. No autopsy.

20. Dr. J. G. Mumford, 1904; age thirty-three, typhoid fever perforation and peritonitis, twenty-four hours' duration, pulse 120, respiration 28, temperature 105, white count 4,300, tympanites (?); one incision; treated dry, Mixter tube in perforation in jejunum, drainage, cloudy fluid with flakes of fibrin throughout; no culture. Died in six hours. No autopsy.

21. Dr. J. G. Mumford, 1904; age fifty-five, appendicitis, peritonitis, four days' duration, pulse 120, respiration 28, temperature 104.4, whites 11,000, tympanites; median incision, treated dry, Mixter tube in cecum, appendectomy, drainage, pus throughout; no culture. Died in ten hours. No autopsy.

22. Dr. F. G. Balch, 1904; age sixty-seven, appendicitis, peritonitis, five days' duration, pulse 120, respiration 30, temperature 101.8, whites 19,000, tympanites; one incision, irrigation, Mixter tube in ileum, appendectomy, drainage, foul pus throughout; no culture; fistula used for drainage, lavage, stimulation and catharsis. Died in thirty-six hours. No autopsy.

23. Dr. R. B. Greenough, 1904; age twenty-one, appendicitis, peritonitis, seven hours' duration (appendicitis, five days' duration), pulse 140, respiration 24, temperature 101, whites 9,000, no tympanites; 5 incisions, irrigation, appendectomy, Mixter tube in cecum, drainage, thin pus throughout; colon bacillus and bacillus mucosus capsulatus. Patient survived the symptoms of diffuse peritonitis but died on thirteenth day from pelvic abscess. No autopsy.

24. Dr. D. F. Jones, 1904; age thirty-four, appendicitis, peritonitis; operation for local abscess four days after first symptoms, five days later diffuse peritonitis and second operation, pulse 124, respiration 30, temperature 99.8, whites 62,000, tympanites; one incision, irrigation, Mixter tube in ileum, drainage, pus throughout, no culture, fistula used for drainage, and for introduction of nourishment and cathartics. Died in forty-eight hours. No autopsy.

SECONDARY ENTEROSTOMY.

25. Dr. C. L. Scudder, 1901; age forty, pyo-salpingitis, diffuse peritonitis, two days' duration, pulse 120, respiration 32, temperature 100.8, whites 26,000, tympanites; one incision, irrigation, salpingectomy, drainage, pus throughout; no growth on culture, bacteria by cover glass; twenty-four hours later Mixter tube in ileum for distention, cathartics introduced by fistula, drainage. Died in thirty hours. No autopsy.

26. Dr. C. A. Porter, 1901; age fourteen, appendicitis, peritonitis, twenty-four hours' duration, pulse 124, respiration 36, temperature 100.8, whites 17,000, tympanites (?); 3 incisions, irrigation, drainage; pus throughout; forty-eight hours later Mixter tube in colon, drainage. Died in twelve hours. Autopsy, acute general fibrino-purulent peritonitis.

27. Dr. F. G. Balch, 1901; age twenty-one, perforated duodenal ulcer, twenty-four hours' duration, pulse 120, respiration 30, tem-

perature 102.4, whites 24,000, no tympanites; 2 incisions, irrigation, drainage, appendix removed, thin pus throughout; culture showed diplococci, varied bacteria by cover glass; twenty hours later Mixter tube in ileum on right for distention, used for stimulation and drainage. Died in twelve hours. Autopsy, general purulent peritonitis, from perforated duodenal ulcer.

28. Dr. F. G. Balch, 1901; age twenty-four, appendicitis, peritonitis, two days' duration, pulse 112, respiration 21, temperature 103, whites 15,000, tympanites (?); one incision, dry sponging, drained, pus in right flank, turbid serum in left flank, pelvis and between coils; culture of serum, colon bacillus; forty eight hours later Mixter tube in ileum on right for distention and vomiting. Died in six hours. No autopsy.

29. Dr. C. A. Porter, 1902; age forty-four, appendicitis, peritonitis, two and a half days' duration, pulse 120, respiration 30, temperature 102, whites 23,000, no tympanites; 2 incisions, irrigation, appendectomy, drainage; pus throughout; culture colon bacillus; forty-eight hours later Mixter tube in cecum. Died in ten hours. No autopsy.

30. Drs. F. Cobb and C. A. Porter, 1902; age fifty-two, peritonitis after ileo-colostomy, three days' duration, pulse 130, respiration 30, temperature 101.6, whites 14,200, tympanites; one incision, drainage; no irrigation, pus in right flank and between coils; no culture; seventy-two hours later Mixter tube in ileum, drainage. Died in twenty hours. Autopsy, general purulent peritonitis.

31. Dr. S. J. Mixter, 1901; age seventeen, appendicitis, peritonitis, duration four days, pulse 90, respiration 24, temperature 102.6, whites 24,600, slight tympanites; one incision, irrigation, drainage; pus throughout; colon bacillus and streptococcus; four days later Mixter tube in cecum for distention, used for drainage and catharsis. Died twelve hours later. No autopsy.

32. Dr. W. A. Brooks, Jr., 1901; age nineteen, appendicitis, peritonitis, three days' duration, pulse 112, respiration 34, temperature 101.4, whites 14,800, slight tympanites; 2 incisions, irrigation and drainage, pus throughout; no culture; twelve hours later Mixter tube in "bowel," drainage and catharsis. Died in ten hours. No autopsy.

33. Dr. E. A. Codman, 1901; age nineteen, appendicitis, peritonitis, two days' duration, pulse 120, respiration 20, temperature 100.2, whites 13,400, no tympanites; one incision, dry sponging, no irrigation, drainage; turbid serum throughout; colon bacilli; five days later Mixter tube in presenting coil. Died in four hours. No autopsy.

34. Dr. E. A. Codman, 1901; age thirty, appendicitis, peritonitis, two days' duration, pulse 88, respiration 24, temperature 99, whites 28,700, slight tympanites, one incision, appendectomy, irrigation, drainage, fluid throughout; no growth of bacteria by culture, no cover glass examination; four days later Mixter tube in presenting coil of bowel for distention, with relief, opening closed on fourteenth day by purse-string without leakage. Recovery. Ten months later intestinal obstruction by adhesions, operation and recovery.

35. Dr. R. B. Greenough, 1901; age forty-eight, perforation gastric ulcer, peritonitis, twelve hours' duration, pulse 96, respiration 28, temperature 97, whites 12,000, slight tympanites; one incision, perforation closed, irrigation, drainage, milky contents of stomach throughout; no culture; forty-eight hours later Mixter tube in cecum for distention. Died in three hours. No autopsy.

36. Drs. M. H. Richardson and J. G. Mumford, 1900; age twenty-three, traumatic rupture of liver and intestine, two days' duration, pulse 104, respiration 24, temperature 100, no blood count, slight tympanites; one incision, resection of part of liver, suture of intestine, irrigation, puncture of bowel and injection of magnesium sulphate, drainage, blood throughout peritoneal cavity; no cultures; forty-eight hours later Mixter tube in ileum for distention, fistula used for drainage and cathartics. Died in forty-eight hours more. No autopsy.

37. Dr. Farrar Cobb, 1900; age twenty-eight, stabwound of intestine and peritonitis, twenty-four hours' duration, pulse 140, respiration 31, temperature 104, no white count; one incision, closure of intestinal wound, irrigation, drainage, pus and feces throughout cavity; five days later Mixter tube in presenting coil for distention. Died in twenty-four hours. No autopsy.

38. Dr. Farrar Cobb, 1901; age eight, appendicitis, peritonitis, two days' duration, pulse 145, respiration 50, temperature 103, whites 32,000, no tympanites; one incision, appendectomy, irrigation, drainage; pus throughout; no growth on culture; twenty-four hours later Mixter tube in sigmoid for distention, fistula used for drainage, lavage and for introduction of nourishment and cathartics, distention relieved. Died six days later with flat abdomen, pelvic abscess and opening in bladder. No autopsy.

39. Dr. Farrar Cobb, 1902; age twenty-four, appendicitis, peritonitis, two days' duration, pulse 104, respiration 34, temperature 103.4, no white count, tympanites; 2 incisions, appendectomy, irrigation, drainage; cloudy fluid containing colon bacilli by cover glass and culture throughout cavity; forty-eight hours later Mixter tube in presenting coil for distention. Died in two hours. No autopsy.

40. Dr. C. L. Scudder, 1901; age fifty-six, peritonitis from perforation above cancer of colon, six days' duration, pulse 128, respiration 28, temperature 100.8, tympanites, no blood count; 2 incisions, irrigation, suture of colon for later enterostomy, drainage; pus throughout; colon bacillus; colon opened by incision on third day, no improvement. Died two days later. Autopsy, general fibrinopurulent peritonitis.

41. Dr. M. H. Richardson, 1904; age six, appendicitis, peritonitis, three days' duration, pulse 150, respiration 60, temperature 102,whites 40,000, no tympanites; one incision, irrigation, drainage; pus throughout; no cultures; three days later, ileum opened in wound for distention with immediate relief. Fistula used for drainage, but nourishment introduced was not retained; another fistula high in jejunum developed spontaneously on fifth day (?), digestion of wound occurred and patient died on ninth day of starvation and sepsis. Distention recurred just before death. No autopsy.

REFERENCES.

[1] Borszczky and Generisch: Beit. klin. Chir., 1903, xxxvi, Heft 2.
[2] Burkhardt: Deut. Zeit. f. Chir., 1901, Vol. lx, p. 369.
[3] Doyen: Zentral. f. Chir., 1902, Supplement, p. 78.
[4] Escher: Mittheil. aus der Grenzge., 1903, xi, p. 104.
[5] Finney and Pancoast: American Medicine, 1903, Aug. 22, p. 305.
[6] Follis: Johns Hopkins Bulletin, 1903, Vol. xiv, p. 87.
[7] Hadra: New York Medical Journal, 1894, June 2.
[8] Heidenhain: Archiv. f. klin. Chir., 1902, Vol. lxvii, p. 929.
[9] Henrotin: American Journal Obstetrics, 1893, August.
[10] Kocher: Mittheil. aus der Grenzge., 1899, Vol. iv, p. 196.
[11] Körte: Mittheil. aus der Grenzge., 1897, Vol. ii, p. 145.
[12] Körte: von Bergmann, Bruns & Mikulicz, Praktischen Chir., article on Peritonitis.
[13] Kukula: Archiv. f. klin. Chir., 1901, Vol. lxiii, p. 773.
[14] Lennander: Deut. Zeit. f. Chir., 1901, Vol. lxiii, p. 1.
[15] Lund: Journal American Medical Association, 1903, July 11.
[16] Madden: Lancet, 1902, ii, p. 1533.
[17] Marsh: Lancet, 1894, ii, p. 973.
[18] McCosh: Annals of Surgery, 1897, Vol. xxv, p. 687.
[19] Meisel: Beit. zur klin. Chir., 1903, Vol. xl, Heft 2 and 3, p. 529.
[20] Mixter: Boston Med. and Surg. Jour., 1895, Vol. cxxxii, p. 206.
[21] Nothnagel: Spec. Pathologie und Therapie, Vol. xvii, Part 3.
[22] Ochsner: Jour. Amer. Med. Assn., 1903, Aug. 29, Discussion of paper by R. H. Gibbons.
[23] Paul: Brit. Med. Jour., July 23, 1892.
[24] Pond: New York Med. Rec., 1898, Vol. liii, p. 582.
[25] Porter: New York Med. News, 1897, p. 134.
[26] Schlange: von Bergmann, Bruns & Mikulicz, Praktischen Chir., article on Intestinal Obstruction.
[27] Sprengel: Zentral. f. Chir., 1902, Supplement, p. 78, Discussion.
[28] Treves: Operative Surgery, Vol. ii, p. 335.
[29] van Arsdale: Annals of Surgery, 1899, Vol. xxix, p.1.
[30] Weber: Beit. zur klin. Chir., 1903, xxxix, No. 2.
[31] Werth: Central. f. Gynec., 1899, p. 1213.